Chapter 5: Cost

CHAPTER CONTENTS

CHAPTER OVERVIEW

This chapter presents a comparative cost analysis of solvent-based, water-based, and UV-cured ink systems. The costs evaluated include material, labor, capital, and energy costs. These elements were chosen because of their importance to facility profitability, their potential to highlight differences among ink systems, and the availability of data. Because this analysis averages industry information, it may not reflect the actual experience of any given printing facility.

Printers who are considering switching ink systems also should evaluate other hidden costs such as regulatory compliance, insurance, storage, clean-up, waste disposal, and permitting. Although estimating these cost factors is beyond the scope of this analysis, this chapter provides a qualitative discussion of these costs.

DEVELOPMENT OF COSTS: Section 5.1 discusses the data sources and methodology used to determine the costs of the four expense categories studied: material, labor, capital, and energy. Because each of these costs were derived quite differently, they are discussed separately. In general, data were collected from three types of sources: performance demonstration observations, industry surveys, and estimates by industry contacts. Some of the costs are highly sensitive to press speed; as a result, some of the figures are calculated based on both the press speeds observed during the performance demonstrations and the speed specified in the project's methodology. Uncertainties of the cost analysis are also presented. A detailed methodology of the cost analysis is located in Appendix 5-A.

COST ANALYSIS RESULTS: Section 5.2 summarizes the overall costs based on the expense categories. Costs are presented by ink system and by ink-substrate combination. The analysis shows the relative costs of each ink system, and also indicates the cost drivers within each system. Detailed results of the cost analysis are provided in Appendix 5-B.

DISCUSSION OF ADDITIONAL COSTS: Section 5.3 discusses costs that often are often hidden from typical accounting analyses but that can affect company profits. These include regulatory costs, insurance and storage costs, and costs related to worker health and natural resource use.

HIGHLIGHTS OF RESULTS

- **Material costs (ink and additives) and capital costs were the two most significant expense categories**. Each accounted for approximately 40% of the costs considered in this analysis.
- **Water-based inks had the lowest material costs**. Water-based inks were consumed at a lower rate than solvent-based ink and had a lower per-pound cost than UV-cured inks.
- **Labor costs were lowest for solvent-based inks at the observed press speeds**, primarily because solvent-based inks were printed at the fastest speeds. When labor costs were calculated for the methodology speed, labor costs were equal across the three ink systems.
- **Water-based inks had the lowest per-hour capital costs**, because the presses did not require pollution control equipment or UV curing lamps. However, **solvent-based inks had the lowest per-image capital costs** because of the higher observed press speeds.
- **Water-based inks had the lowest energy costs**. The primary reason for these lower costs is that water-based inks did not require pollution control equipment or UV curing lamps.
- **Overall, water-based inks were the least expensive to use.** Solvent-based inks were the next least expensive, followed by UV-cured inks.

CAVEATS

- Costs were calculated based on both the observed press speeds and the methodology press speed of 500 feet per minute. Press speed is crucial to cost estimates because if more product can be printed in a given time, then fixed costs (e.g., capital and labor) are distributed across more salable product. If customary press speeds at a facility are significantly different from those used for this analysis, actual costs may be different.
- The costs presented in this analysis do not represent all expenses encountered at a flexographic printing facility. One significant factor that was excluded was substrate (the material, such as film, that is printed). Substrates are a major expense, but because their costs are independent of the ink system, they were not included in the analysis. Other costs, such as those discussed qualitatively in Environmental and Regulatory Costs, also are not included in the quantitative results.
- Assumptions in this analysis may not apply to all facilities. For example, it was assumed that pollution control equipment is not necessary with water-based ink systems. In some locations, oxidizers in fact may be required if inks exceed regulatory minimum VOC content thresholds.

5.1 DEVELOPMENT OF COSTS

This section discusses the categories of costs that were analyzed for the different ink systems, formulas that were used in calculations, and assumptions that were made. This information will allow the reader to understand the basis for the results that are described in the next section.

The primary sources of data were the performance demonstrations and estimates provided by flexographic printers and suppliers. The model facility used in the risk assessment section was also used for the cost analysis. Model facility assumptions were based on averages of the information reported in the questionnaire completed by each performance demonstration site. A detailed methodology of the cost analysis is in Appendix 5-A.

Material Costs

The material costs estimated in this analysis are inks and additives. Representative substrate costs are also presented in this section to give a fuller picture of printing costs, but substrate is not included in the rest of the analysis because during production, its costs do not vary among ink systems. The specific prices that any given printer pays for materials are expected to vary with the volume purchased and the relationship between printer and supplier.

Ink Costs

Ink prices vary with the type of ink (solvent-based, water-based, or UV-cured) and color. Generally speaking, white inks are least expensive, primary colors are slightly more expensive, and other colors or custom colors are most expensive.

For this analysis, one price was estimated for white ink and one for the other four colors. These ink prices are listed in Table 5.1. It is important to note that these are average prices, and the price that a printer pays may be either higher or lower than those presented here.

Table 5.1 Average Ink Prices[a]

	Solvent-based ($/lb)	Water-based ($/lb)	UV-cured ($/lb)
White	$1.40	$1.60	$7.25
Other colors	$2.80	$3.00	$10.00

[a] Based on November 1998 prices.
Source: References 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13.

To determine ink consumption costs, the ink prices were multiplied by the amount of ink used for each performance demonstration run. In addition, the test image dimensions and repeat length were used in the calculations. Information about the test image is presented below. The repeat length indicates the distance from the beginning of an image to the beginning of the first repetition of the image.

Test Image Information
Line colors: blue, green, and white
Process colors: cyan and magenta
Image dimensions: 16 inches x 20 inches (320 sq. inches or 2.22 sq. feet)
Repeat length: 16 inches (1.33 feet)

The ink costs per 6,000 images and per 6,000 ft^2 of image were calculated using the following formulas:

Ink cost per 6,000 images $= I \times 2.22\ ft^2/\text{image} \times 6{,}000$ images
Ink cost per 6,000 ft^2 of image $= I \times 6{,}000\ ft^2$

where

$$I = \text{ink price (\$/lb)} \times \text{amount of ink used (lb)} / \text{amount of substrate used } (ft^2)$$
$$= \text{ink cost per } ft^2\ (\$/ft^2)$$

Tables 5.2 and 5.3 present the average ink costs for each ink-substrate combination per 6,000 images and per 6,000 ft^2 of image, respectively. The site-specific ink costs and a sample calculation are provided in Appendix 5-B. Both ink and ink additives are included in the average costs, and a detailed table providing site-specific consumption data is provided in Appendix 6-A.

Additive Costs
In most of the performance demonstration runs, additives were mixed with the inks to achieve and maintain desired viscosity and performance. Specifically, extenders, solvents, and/or water were added to the solvent-based and water-based inks. Also, ammonia, reducers, cross-linkers, and/or defoamers were added to the water-based inks, and acetate was added to one solvent-based ink (Site 10). No additives were used in the UV-cured ink performance demonstrations, with the exception of a low-viscosity monomer added to the green ink at one site (Site 11).

The methodology for estimating ink additive costs was similar to that for inks. Based on input from printers and suppliers, the DfE team determined average prices for each additive.[1,3,13,14] Extender was \$2.00/lb, solvent was \$1.00/lb, water was given no charge, and other solvent- and water-based ink additives were \$0.45/lb. A price for the UV additive (monomer) was not determined, because ink manufacturers state that extra monomer is not typically added to UV ink at press side.

The additive costs per 6,000 images and per 6,000 ft^2 of image were calculated using the same formulas as for the normalized ink costs.

The estimated average ink additive costs for each ink-substrate combination also are presented in Tables 5.2 and 5.3. The site-specific ink additive costs are provided in Appendix 5-B.

Table 5.2 Average Ink and Additive Consumption and Costs from the Performance Demonstrations (per 6,000 Images)

	White ink			Colored ink			Extender			Solvent			Other Additives			TOTALS	
	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Avg. cost
Solvent-based ink																	
LDPE	7.37	$1.40	$10.31	10.66	$2.80	$29.83				5.61	$1.00	$5.61				23.63	$45.76
PE/EVA[c]				10.66	$2.80	$29.83				3.78	$1.00	$3.78				14.43	$33.61
OPP	7.86	$1.40	$11.00	5.54	$2.80	$15.51	0.16	$2.00	$0.32	4.44	$1.00	$4.44	0.78	$0.45	$0.35	18.78	$31.62
Water-based ink																	
LDPE	6.53	$1.60	$10.44	4.26	$3.00	$12.78	0.16	$2.00	$0.32	0.26	$1.00	$0.26	0.64	$0.45	$0.29	11.84	$24.09
PE/EVA[c]				4.26	$3.00	$12.78				0.07	$1.00	$0.07	0.37	$0.45	$0.45	4.70	$13.01
OPP	6.78	$1.60	$10.85	3.58	$3.00	$10.73	0.19	$2.00	$0.38	0.17	$1.00	$0.17	0.08	$0.45	$0.04	10.80	$22.17
UV-cured ink																	
LDPE	5.19	$7.25	$37.59	2.52	$10.00	$25.20							[e]			7.72	$62.80
PE/EVA[c]				1.89	$10.00	$18.85										1.89	$18.85
OPP	n/a[d]	n/a	n/a	n/a	n/a	n/a										n/a	n/a

[a] Ink prices may vary from the stated average, so pounds of ink are reported here to allow readers to customize the results to apply to their own situation.
[b] Ink prices are for November, 1998.
[c] PE/EVA is a white substrate, so white ink is not used with it.
[d] n/a = not applicable; there were no successful runs of UV-cured ink on OPP in the performance demonstrations.
[e] UV ink manufacturers state that extra monomer is typically not added to UV ink; the printer for this demonstration run did add monomer. The cost of this monomer is not known.

Table 5.3 Average Ink and Additive Consumption and Costs from the Performance Demonstrations (per 6,000 ft^2)

	White ink			Colored ink			Extender			Solvent			Other Additives			TOTALS	
	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Price ($/lb)[b]	Avg. cost	Avg. lbs.[a]	Avg. cost
Solvent-based ink																	
LDPE	3.32	$1.40	$4.64	4.80	$2.80	$13.44			$0.00	2.53	$1.00	$2.53				10.65	$20.61
PE/EVA[c]				4.80	$2.80	$13.44			$0.00	1.70	$1.00	$1.70				6.50	$15.14
OPP	3.54	$1.40	$4.95	2.49	$2.80	$6.97	0.08	$2.00	$0.15	2.00	$1.00	$2.00	0.35	$0.45	$0.16	8.45	$14.23
Water-based ink																	
LDPE	2.94	$1.60	$4.70	1.91	$3.00	$5.72	0.07	$2.00	$0.14	0.12	$1.00	$0.12	0.29	$0.45	$0.13	5.32	$10.80
PE/EVA[c]				1.91	$3.00	$5.72				0.03	$1.00	$0.03	0.17	$0.45	$0.07	2.10	$5.82
OPP	3.05	$1.60	$4.89	1.60	$3.00	$4.81	0.09	$2.00	$0.18	0.08	$1.00	$0.08	0.04	$0.45	$0.02	4.86	$9.97
UV-cured ink																	
LDPE	2.33	$7.25	$16.89	1.14	$10.00	$11.35							[e]			3.47	$28.24
PE/EVA[c]				0.85	$10.00	$8.50										0.85	$8.50
OPP	n/a[d]	n/a	n/a	n/a	n/a	n/a										n/a	n/a

[a] Ink prices may vary from the stated average, so pounds of ink are reported here to allow readers to customize the results to apply to their own situation.
[b] Ink prices are for November, 1998.
[c] PE/EVA is a white substrate, so white ink is not used with it.
[d] n/a = not applicable; there were no successful runs of UV-cured ink on OPP in the performance demonstrations.
[e] UV ink manufacturers state that extra monomer is typically not added to UV ink; the printer for this demonstration run did add monomer. The cost of this monomer is not known.

Substrate Costs

Substrate costs are a function of the price of the substrate and the amount of substrate used. Based on input from printers and suppliers, an average price was determined for the three types of substrate used in the performance demonstrations — LDPE, PE/EVA, and OPP. Table 5.4 presents the substrate prices, the conversion factors used to convert square feet of substrate to pounds, and the substrate costs. The substrate costs per 6,000 images and per 6,000 ft^2 of image were calculated using the following formulas:

$$\text{Substrate cost per 6,000 images} = S \times 2.22\ ft^2/\text{image} \times 6{,}000\ \text{images}$$
$$\text{Substrate cost per 6,000 } ft^2 \text{ of image} = S \times 6{,}000\ ft^2$$

where

$$S = \text{substrate price (\$/lb)} \times \text{conversion rate } (lb/ft^2)$$
$$= \text{substrate cost per } ft^2\ (\$/ft^2)$$

Table 5.4 Average Substrate Costs and Conversion Rates (ft^2 to lbs)

Substrate	Price ($/lb)	Conversion rate (lb/ft^2)	Substrate cost per ft^2 ($\$/ft^2$)	Average cost per 6,000 images	Average cost per 6,000 ft^2 of image
LDPE	$0.77	0.0134	$0.01	$138	$62
PE/EVA	$0.82	0.0258	$0.02	$282	$127
OPP	$1.50	0.0072	$0.01	$144	$65

Sources: References 2, 3, 5, 7, 9, 10, 11, 12, 13, 15, 16.

Substrate costs are not included in the cost analysis. The price of substrate can be quite variable and therefore would introduce additional uncertainty to the analysis. Also, because substrate consumption does not vary by ink system, it does not need to be included in comparisons between systems. Average substrate costs are supplied above, however, to provide a more complete tally of total costs a printer might encounter.

Labor Costs

For this cost analysis, labor costs are primarily a function of printers' compensation rates and the time it takes to print the product. Labor rates include the wage rate of a press operator and one assistant, the fringe rate, and the overhead rate. This cost analysis assumes that labor rates do not vary with the ink system or the substrate.

Wage Rate

Industry sector-specific wage rates are typically available from the U.S. Department of Labor; however, obtaining an average flexographic industry labor rate was complicated by the fact that the flexographic industry sector is combined with other printing sectors in SIC 2759. To obtain a wage rate indicative of the industry sector, an average hourly wage rate for the industry of $11.49[17] was used as a baseline and confirmed by performance demonstration site contacts in 1997.[2,4,5,7,11,12,15,18]

Fringe Rate

The average press operator or assistant received fringe benefits of holidays, vacations, sick leave, supplemental pay (premium pay for overtime work on weekends and holidays, shift differentials, and non-production bonuses such as lump-sum payments provided in lieu of wage increases), insurance benefits (life, health, sickness, and accident), and legally required benefits (Social Security). In private industry, blue-collar workers had an average fringe rate of 26.5% of total compensation.[19] Total compensation of $15.63 per hour includes a fringe rate of $4.14 per hour.

Overhead Rate

The overhead factor for the flexographic industry was calculated using the following formula:

Overhead factor = (overhead costs) / (direct labor)

Overhead costs = Rent and heat + fire and sprinkler insurance + indirect labor + direct supplies + repair to equipment + general factory + administrative and selling overhead

Using data from the flexographic industry and the above formula, the average industry overhead factor was 0.41, or an overhead rate of $6.41/hour. For a detailed look at how the overhead rate was calculated, see Appendix 5-A.

Based on the wage, fringe, and overhead rates listed in Table 5.5, the overall labor rate for each worker was $22.04 per hour, or $44.08 per hour for both a press operator and assistant.

Table 5.5 Summary of Labor Rate Calculations

Labor cost component	Calculation	Rate ($/hr)
Wage rate	from industry estimates	$11.49
Fringe rate	26.5% of total compensation[a]	$4.14
Overhead rate	0.41 times total compensation[a]	$6.41
Total per-worker labor rate		**$22.04**

[a]Total compensation equals wage plus fringe.

Total Labor Cost

To calculate the total labor cost, the labor rate was multiplied by the average amount of time generally needed to print 6,000 images and 6,000 ft^2 of image (based on press speed). This simplified calculation omits makeready and clean-up costs. The labor cost estimates were calculated using the following formulas:

Labor cost per 6,000 images = $L \times 2.22\ ft^2/image \times 6{,}000$ images

Labor cost per 6,000 ft^2 of image = $L \times 6{,}000\ ft^2$

where

L = labor rate (\$/hour) × repeat length per ft^2 of image (ft/ft^2) / press speed (ft/hour)
= labor cost per ft^2 ($\$/ft^2$)

Assuming an average press speed for a flexographic press was extremely difficult. Variables such as the test image, the age of the press, the desired quality of the product, and the skill of the press operator affect the press speed considerably. The performance demonstration methodology dictated a press speed of 300 to 500 feet per minute (fpm). Therefore, the site demonstrations were not illustrative of the potential of a press for a specific ink system. Presses may have been held back from or pushed beyond their optimal running speeds. Using the typical production speed of the press reported by the facility was not realistic because of the variety of product quality. For example, one site ran at 700 fpm and produced a low quality product whereas another site ran at 350 fpm and produced a very high quality product. Finally, few data exist that support an industry average press speed for each ink system.

The cost analysis used the average press speed from the performance demonstrations (Table 5.6) for each ink type to determine labor and capital costs. The parenthetical numbers in the first row indicate the number of demonstration runs on which the data are based.

Table 5.6 Average Press Speed Data from the Performance Demonstrations

	Solvent-based	Water-based	UV-cured
Average feet per minute	453 (6)	394 (7)	340 (4)
Average feet per hour	27,200	23,600	20,400

Table 5.7 presents average labor costs for each ink system using the average observed press speed and the methodology press speed (500 feet per minute). When the methodology press speed is used, the labor costs were neutralized for the three ink systems. When the average observed press speeds are used, the labor cost is lowest for solvent-based inks (i.e., these ran at the fastest press speeds during the demonstrations). Compared to solvent-based inks, the labor cost for water-based inks was 15% higher, and the labor rate for UV-curable inks was 33% higher. The site-specific labor costs and a sample calculation are provided in Appendix 5-B.

Table 5.7 Labor Costs Based on Press Speeds

Ink	Labor rate ($/hr)	Press speed (ft^2/hr)	Labor cost per ft^2 ($/$ft^2$)	Average cost per 6,000 images	Average cost per 6,000 ft^2 of image
Based on Observed Performance Demonstration Press Speeds					
Solvent-based	$44.08	45,300	$0.000973	$12.96	$5.84
Water-based	$44.08	39,400	$0.00112	$14.90	$6.71
UV-cured	$44.08	34,000	$0.00130	$17.27	$7.78
Based on Methodology Press Speed – 500 Feet per Minute					
Solvent-based	$44.08	50,000	$0.000882	$11.74	$5.29
Water-based	$44.08	50,000	$0.000882	$11.74	$5.29
UV-cured	$44.08	50,000	$0.000882	$11.74	$5.29

Capital Costs for New Presses

Capital costs are those costs associated with purchasing or modifying the equipment. Two scenarios were examined: buying a new press outfitted for a specific ink technology and retrofitting an existing press from one ink technology to another.

The data used for capital costs were acquired from press manufacturers, suppliers, and flexographic printers. The capital costs were not gathered at the performance demonstration sites due to the variances in the ages of the presses and, therefore, in the representativeness of the costs.

The capital cost of a new press included the cost of a base press plus any modifications required for each ink system. The base press was assumed to be an eight-color, 48-inch press. The cost for a base press also included installation. The cost of a new base press ranged from $600,000 to $5 million, with an average cost of about $2.5 million.[9,10,13,14,16,17,20] The base press cost included the cost of the following:

- chambered doctor blades
- peristaltic ink pumps
- chill rollers
- covered ink/water rollers
- forced hot air dryers (between-color and overhead final)
- electrical drive
- in-feed devices
- ink agitators
- rewind unit
- roll stands/reels
- water union
- web break detectors
- press installation
- one-week training

The exception to the above list is that a UV press will not require hot air dryers; the base price for a UV press therefore would be reduced to reflect the absence of this approximately $100,000 equipment.[21] All other equipment modifications specific to the ink systems were added to the base press cost. These costs included the cost of pollution control devices which might have been required if solvent-based inks were used, the cost of UV lamps, etc. A summary of the capital costs is presented in Table 5.8, followed by a more detailed discussion of each ink system.

Table 5.8 Summary of Capital Costs for New Presses

Ink	Base press cost ($)	Additional Components	Additional cost ($)	Total capital cost ($)
Solvent-based	$2.5 million	pollution control	$128,000	$2.6 million
Water-based	$2.5 million	corona treater	$25,000	$2.5 million
UV-cured	$2.4 million	corona treater, UV lamps, power supplies, and cooling units	$200,000	$2.6 million

Solvent-based Ink Presses

The primary additional equipment expense in running solvent-based ink is an oxidizer needed for pollution control. The analysis assumed that an "average" wide web facility has four 48" presses and two catalytic oxidizers, with an air flow of 5,800 cubic feet per minute (cfm) to each oxidizer. The cost estimates, based on these characteristics, are shown in Table 5.9.

Table 5.9 Catalytic Oxidizer Costs[a]

Component	Cost
Oxidizer	$200,000
Installation	$50,000
Testing	$5,000-$6,000
Total	**$255,000**

[a]These costs represent an oxidizer serving two presses. The per-press costs used in the analysis are half of these amounts.
Source: References 22 and 23.

Because each oxidizer is assumed in this analysis to control the emissions from two presses, this cost is spread over two presses. Therefore, the cost of a pollution control system per press is expected to be $128,000. This cost may vary depending on facility-specific variables, such as the location of the oxidizer, duct runs, location in the country, and whether the duct is insulated.[14]

An alternative type of oxidizer is the regenerative thermal oxidizer (see Chapter 7 for details). The cost of purchasing, installing, and testing this system is similar to that of a catalytic oxidizer. During operation, it may result in lower costs because the catalyst does not need to be replaced. Including the cost of either type of oxidizer, a press using a solvent-based ink system was estimated to cost $2.6 million.

Water-based Ink Presses

A new water-based press will come equipped with all necessary equipment, with the exception of a corona treater. A corona treater costs approximately $25,000,[24] resulting in a total cost estimate of $2.5 million for a press using a water-based ink system.

UV-cured Ink Presses

The primary cost for UV-cured ink presses is the UV curing system. The equipment consists of lamps, power supplies, cooling units, and a corona treater. According to a press manufacturer, this equipment costs approximately $200,000 for a wide web flexographic printing press.[20] This resulted in an estimate of $2.6 million for a press using a UV-cured ink system.

Total Capital Costs for New Presses

To incorporate capital costs into this cost analysis, the capital costs were annualized (and calculated on an hourly basis) per 6,000 images and per 6,000 ft^2 of image. The annual expense can be translated into an hourly expense by dividing by the annual operating hours.

The annual cost was determined by a present-worth-to-annuity calculation, as follows:

$$A = T * \frac{i(1+i)^n}{(1+i)^n - 1}$$

A = annual capital cost
T = total cost (price of press)
i = interest or depreciation rate
n = lifetime of equipment

The average annual industry depreciation rate was 15% per year,[25] and the estimated lifetime of a press not subject to a substantial modification or upgrade is 20 years.[21] The hourly capital cost estimates were based on the following calculation:

Capital cost per 6,000 images = C × 2.22 ft^2/image × 6,000 images
Capital cost per 6,000 ft^2 of image = C × 6,000 ft^2

where

C = capital cost per ft^2 (\$/ft^2)
= hourly capital cost (\$/hr) × repeat length per ft^2 of image (ft/ft^2) / average press speed (ft/hr)

and

Depreciation rate	=	15%
Annual operating hours	=	4,200 hours per year
Hourly capital cost ($/hr)	=	A ($/yr) / annual operating hours (hr/yr)
	=	A ($/yr) / 4,200 hours per year

Table 5.10 presents the hourly capital costs of each ink system.

Table 5.10 Capital Costs for New Presses

	Capital cost ($)	Hourly capital cost ($)	Cost per ft^2 of image	Cost per 6,000 images	Cost per 6,000 ft^2 of image
Based on Observed Performance Demonstration Press Speeds					
Solvent-based	$2.6 million	$98.90	$0.00218	$29.08	$13.10
Water-based	$2.5 million	$95.10	$0.00241	$32.15	$14.18
UV-cured	$2.6 million	$98.90	$0.00291	$38.75	$17.45
Based on Methodology Press Speed – 500 Feet per Minute					
Solvent-based	$2.6 million	$98.90	$0.00198	$26.35	$11.87
Water-based	$2.5 million	$95.10	$0.00190	$25.33	$11.41
UV-cured	$2.6 million	$98.90	$0.00198	$26.35	$11.87

Capital Costs for Retrofitting a Press

Alternatively a printer may retrofit an existing press for a new technology rather than purchase a new press. The feasibility and costs of a retrofit need to be addressed on a case-by-case basis, because retrofitting costs can vary considerably depending on the age and type of press. The newer the press, the fewer and easier the changes. For example, most newer presses come equipped with diaphragm or peristaltic ink pumping systems and chambered doctor blades. This analysis presents *possible* capital costs that may be incurred for a retrofit; if newer equipment such as that mentioned above were present, the retrofit process would be less expensive.

In this analysis, retrofit costs included only the additional costs of equipment. The labor, training, and downtime costs associated with a retrofit were not included because these costs are highly variable and situation-specific. This analysis assumed a retrofit on an older, six-color, 48-inch press. The following cost estimate of the equipment necessary for the change to a new ink system was developed from discussions with printers who have changed ink systems and from discussions with manufacturers and suppliers who are familiar with the changes.

Solvent-based to Water-based Ink System
A retrofit from an older solvent-based ink system to a water-based ink system may require some of the following equipment changes depending on the age of the press:[16]

- reconfiguring anilox rolls
- adding chambered doctor blades
- adding diaphragm or peristaltic ink pumping systems
- adding a corona treater and auxiliary corona treating material
- adding or retrofitting existing blowers to increase the blowing capacity
- changing plate materials and mounting

Estimates to retrofit from a solvent-based to water-based ink system on a 48-inch press are in the range of $60,000 to $100,000.[9] While a solvent-based ink system press can run water-based ink on well-treated film and at much lower speeds without a retrofit, retrofitting improves substrate wettability and/or increases drying capability.[3]

Solvent-based to UV-cured Ink System

A retrofit from a solvent-based to a UV-cured ink system requires similar equipment changes to those required for a retrofit from a solvent-based ink system to a water-based ink system. The changes required for this retrofit may include the following:[16]

- buying and installing UV-cured lamps and the power units to support the lamps
- purchasing and installing chillers to cool the equipment
- reconfiguring anilox rolls
- adding chambered doctor blades
- adding diaphragm or peristaltic ink pumping systems
- adding a corona treater and auxiliary corona treating material
- changing plate materials and mounting

Retrofits from a solvent-based to UV-cured ink system are estimated to be in the range of $400,000 to $500,000.[9] Given this cost, most printers would probably purchase a new press rather than retrofit an existing one. In addition, many older flexographic printing presses cannot be retrofitted for UV production.[9,14] While the major equipment requirements are listed above, additional engineering or "tinkering" may be necessary to obtain the product quality required. Many flexographic printers, manufacturers, and suppliers do not believe this kind of retrofit can produce a saleable product.[1,3,10,13,26]

Water-based to UV-cured Ink System

In retrofitting a press from a water-based to UV-cured ink system, the following equipment changes are necessary:[16]

- adding UV lamps and power units
- removing blowers
- adding chillers
- possibly adding plate materials

On a six-deck press, retrofit costs are expected to be roughly $30,000 per deck, or $180,000.[5] Water-based ink systems cannot always be retrofitted for UV production. Many flexographic printers, manufacturers, and suppliers do not believe this kind of retrofit can produce a saleable product with an older press, although many new presses are being manufactured with retrofits in mind.[1,3,10,13,26]

UV-cured to Water-based Ink System

Although retrofitting from a UV-cured to a water-based ink system is not common, one site using UV decided to return to a water-based system. The equipment changes included removing the UV lamps, power equipment, and chillers, and adding blowers. If the press had originally been a solvent- or water-based press, then the blowers would simply need to be re-installed, at a cost of approximately \$32,000.[5] If the press had been purchased for a UV-cured ink system, it would be necessary to purchase and install a dryer system, which is estimated to cost approximately \$100,000.[21]

Energy Costs

The energy use for four types of flexographic printing equipment—hot air drying systems, catalytic oxidizers, corona treaters, and UV curing systems—was estimated for the three ink systems (see Chapter 6: Energy and Resource Consumption). Energy costs were calculated using the energy consumption rates for this equipment and national averages of electricity and natural gas costs. Given the typical size and total sales of a flexographic printing facility, an average electricity cost of \$0.0448/kWh[27] and an average gas cost of \$3.14/million Btu[28] were used; however, these figures can vary substantially depending on the location and size of the facility.

To calculate energy costs, electricity and natural gas consumption figures were taken from Chapter 6. Energy costs per 6,000 images and 6,000 ft^2 were then calculated with the following equations:

$$\text{Energy cost per 6,000 images} = (E + G) \times 2.22\ ft^2/\text{image} \times 6{,}000\ \text{images}$$

$$\text{Energy cost per 6,000 } ft^2 \text{ of image} = (E + G) \times 6{,}000\ ft^2$$

where

$$E = \text{electricity cost (\$/kWh)} \times [\text{electricity consumption (kWh/hour)} / \text{press speed (ft/hour)}] \times \text{repeat length per } ft^2 \text{ of image } (ft/ft^2)$$
$$= \text{electricity cost per } ft^2\ (\$/ft^2)$$

$$G = \text{natural gas cost (\$/Btu)} \times [\text{natural gas consumption (Btu/hour)} / \text{press speed (ft/hour)}] \times \text{repeat length per } ft^2 \text{ of image } (ft/ft^2)$$
$$= \text{natural gas cost per } ft^2\ (\$/ft^2)$$

Uncertainties

Efforts were made to obtain data as representative of the industry as possible. However, differences in the ink systems may have had further cost implications that were not captured in the data. Some of the differences may have been difficult to capture in the time span of a two-hour run, may not have been easily quantifiable, or may have been too minute to identify given the methodology and testing. When interpreting the results of this analysis and applying them to a particular operation, the following uncertainties should be considered.

Ink Maintenance

The print run conditions may affect the level of ink maintenance more significantly than was demonstrated at the volunteer sites. UV inks do not dry on anilox rolls or other rolls and hence the color strength remains constant; in addition, during multi-day runs the number of cleanups can be reduced. Using solvent-based inks and water-based inks can increase the amount of labor, run time, clean-up, and waste because of the need to add or remove ink multiple times during a run. These differences, which make UV more competitive, are not reflected in the cost figures due to difficulties in their quantification. Also, industry feedback suggests that UV-cured inks can operate with smaller-volume anilox rolls than were used in the study, the use of smaller-volume rolls would reduce ink consumption for this system relative to the other ink systems.

Productivity

Productivity was another area that was not effectively captured in the performance demonstrations. The performance demonstration methodology specified a printing run at the rate of 300 to 500 fpm. Some sites, however, had to slow down their runs to increase drying times, whereas other sites increased their press speeds for some runs. For example, at Site 10, the press speed was 600 fpm due to the facility's standard operating procedures. The data do not shed light on the controversial issue of whether one ink can be run faster than the others while producing a product quality that is better or comparable to that of the other inks.

Makeready Variables

The experience of the press operators and the type and age of the press have a greater influence on the makeready time than does the type of ink. This is because the main concerns in makeready are registration and the print impression. The amount of substrate used in makeready and the time required for makeready are based on the ability of the press operator to adjust color and viscosity. However, industry experience indicates that proper color strength can be achieved fastest with UV inks.

Clean-up and Waste Disposal Costs

Clean-up and disposal practices were observed qualitatively for the three ink systems at the performance demonstration sites. During the performance demonstrations, the following cleaning agents were used for each ink type:

- Solvent-based ink: alcohol or alcohol/acetate blend
- Water-based ink: water, or water/ammonia/alcohol blend
- UV-cured ink: alcohol, alcohol/acetate blend, or alcohol/water/soap blend

Appendix 6-A presents more detailed information for each site, and Section 6.5, Clean-up and Waste Disposal Procedures, provides more information on these procedures.

Differences in the clean-up components among the three ink systems include the following:

- The materials are least expensive for water-based inks.
- The type of press is a major factor in how long it takes to clean.
- UV presses can be shut down overnight or for extended periods of time without clean-up procedures. If covered, the inks will not cure in the wells, so the press can be started up with minimal ink preparation.

- Solvent-based ink waste is the most expensive to dispose of because it is often characterized as hazardous waste. Water may or may not require the same costs, depending on the solvent content of the ink and location of the facility. UV waste disposal costs may be substantially lower for two reasons: the wastes often are not designated as hazardous under RCRA, and less waste is generated by UV.

Clean-up and waste disposal costs were not included in the quantitative analysis, however, because it was not possible to calculate reliably the costs associated with these procedures.

Site-Specific Limitations
Each printing site was unique, which created some challenges for the performance demonstration. For some of the sites, specific questions or data points were not applicable because of the ink system, the type of site, insufficient data, or the failure of a test run. For these situations, inconsistencies were identified, the data were omitted, or reliable follow-up information was substituted from phone interviews with printers.

Although most of the sites were actual printing facilities, one UV site was a press manufacturer in Germany. The press used at this site was a demonstration version and was not used to print saleable product. As a result, the data from this site did not contain annual or plant-wide costs. Information on clean-up, waste disposal, and ink and substrate costs also was not available. In addition, the makeready at this site was completed before the observation team arrived at the site. Therefore, the makeready data for the time and feet run were not observed by the team.

Another performance demonstration site (Site 11) used a different substrate than specified in the methodology. Demonstrations run at this site used LDPE that was extruded with no slip additives, in accordance with the facility's standard procedure.

5.2 COST ANALYSIS RESULTS

This section presents the results of the cost analysis for each ink-substrate combination. This analysis can help the reader to compare costs among solvent-based, water-based, and UV-cured ink systems. Site-specific cost information is shown in Appendix 5-B.

Summary of Cost Analysis Results

Table 5.11 presents an overall summary of the costs per 6,000 images and per 6,000 ft^2 of image, broken out by substrate and ink type. Table 5.12 provides an average cost breakdown of four major cost elements (materials, excluding substrate; labor; capital for a new press; and energy costs). Table 5.13 presents cost summaries for each performance demonstration site. These costs do not include substrate, makeready or clean-up.

For each substrate, water-based inks were the least expensive. Solvent-based inks were slightly more expensive than water-based inks (1% more for LDPE, 36% more for PE/EVA, and 9% for OPP), and UV-cured inks were the most expensive (29% more than water-based inks on LDPE, 46% more for PE/EVA). When the figures are calculated based on the methodology press speed, water would again be the least expensive. Solvent-based inks would cost 24% more, and UV 38% more than water-based inks. The numbers in parentheses in

Table 5.11 indicates the number of performance demonstration runs on which the data are based.

Table 5.11 Cost Summary for Ink-Substrate Combinations

	Solvent-based		Water-based		UV-cured	
	Cost per 6,000 images	Cost per 6,000 ft^2 of image	Cost per 6,000 images	Cost per 6,000 ft^2 of image	Cost per 6,000 images	Cost per 6,000 ft^2 of image
Based on Observed Performance Demonstration Press Speeds						
LDPE	\$92 (2)	\$42 (2)	\$91 (2)	\$41 (2)	\$117 (2)	\$53 (2)
PE/EVA	\$80 (1)	\$36 (1)	\$59 (2)	\$26 (2)	\$86 (2)	\$39 (2)
OPP	\$72 (2)	\$32 (2)	\$66 (3)	\$30 (3)	n/a[a]	
Based on Methodology Press Speed – 500 Feet per Minute						
LDPE	\$85	\$38	\$62	\$28	\$103	\$46
PE/EVA	\$72	\$33	\$52	\$24	\$57	\$26
OPP	\$72	\$32	\$59	\$27	n/a[a]	

[a]n/a = not applicable; there were no successful runs of UV-cured ink on OPP in the performance demonstrations.

As shown in Table 5.12, material and capital costs (excluding substrate) accounted for the majority of costs. Averaged across the eight ink-substrate combinations, materials (ink and additives) represented 38% of the costs, and capital costs were 41% of the total. Labor accounted for 14% to 24% of the total cost, and energy accounted for 1% to 4%.

Several factors affect press speed, including labor, equipment, and handling. However, because the differing press speeds observed during the performance demonstrations may cause a misrepresentation of the comparative costs associated with the different ink systems, the costs were also calculated based on the methodology speed of 500 fpm. If all three ink systems had been run at the methodology speed, the labor cost differences and some capital cost differences would have been neutralized. Water-based inks would still have been the least expensive. Solvent-based inks would have been more expensive than water-based inks (39% more for LDPE, 38% more for PE/EVA, and 22% for OPP). UV-cured inks would have been the most expensive on LDPE (66% more than water-based inks on LDPE), but would no longer have been the most expensive on PE/EVA (10% more than water-based inks, but 21% less than solvent-based inks).

Table 5.13 presents a cost summary for each performance demonstration site. A detailed breakdown of costs for each site is provided in Appendix 5-B.

Table 5.12 Cost Breakdown for Ink-Substrate Combinations

Substrate	Ink	Component	Average cost per 6,000 images	Average cost per 6,000 ft^2 of image	Percent of total
LDPE	Solvent-based (2 sites)	materials	$46	$21	49%
		labor	$14	$6	15%
		capital	$31	$14	34%
		energy	$1	$1	2%
		total	**$93**	**$42**	**100%**
	Water-based (2 sites)	materials	$24	$11	26%
		labor	$21	$9	23%
		capital	$45	$20	49%
		energy	$1	$1	2%
		total	**$91**	**$41**	**100%**
	UV-cured (2 sites)	materials	$63	$28	53%
		labor	$16	$7	14%
		capital	$36	$16	30%
		energy	$3	$1	3%
		total	**$117**	**$53**	**100%**
PE/EVA	Solvent-based (1 site)	materials	$34	$15	42%
		labor	$14	$6	17%
		capital	$31	$14	39%
		energy	$1	$1	2%
		total	**$81**	**$37**	**100%**
	Water-based (2 sites)	materials	$13	$6	22%
		labor	$14	$6	24%
		capital	$30	$14	52%
		energy	$1	<$1	2%
		total	**$59**	**$26**	**100%**
	UV-cured (2 sites)	materials	$19	$8	22%
		labor	$20	$9	23%
		capital	$44	$20	51%
		energy	$4	$2	4%
		total	**$86**	**$39**	**100%**
OPP	Solvent-based (2 sites)	materials	$32	$14	44%
		labor	$12	$5	17%
		capital	$27	$12	37%
		energy	$1	$1	2%
		total	**$73**	**$33**	**100%**
	Water-based (3 sites)	materials	$22	$10	34%
		labor	$14	$6	21%
		capital	$29	$13	44%
		energy	$1	<$1	1%
		total	**$66**	**$30**	**100%**
	UV-cured	n/a[a]			

[a] n/a = not applicable; there were no successful runs of UV-cured ink on OPP in the performance demonstrations.

Table 5.13 Cost Summary for Each Performance Demonstration Site

Substrate	Ink	Product Line	Site	Cost per 6,000 images	Cost per 6,000 ft^2 of image
LDPE	Solvent-based	#S2	5	$102	$46
			7	$82	$37
	Water-based	#W3	2	$73	$33
			3	$109	$49
	UV-cured	#U1	11	$123	$56
		#U2	6	$111	$50
PE/EVA	Solvent-based	#S2	5	$89	$40
			7	$106	$26
	Water-based	#W3	2	$64	$29
			3	$53	$24
	UV-cured	#U2	6	$83	$37
		#U3	8	$89	$40
OPP	Solvent-based	#S1	9B	$76	$36
		#S2	10	$67	$31
	Water-based	#W1	4	$71	$32
		#W2	1	$66	$30
		#W4	9A	$61	$27
	UV-cured	n/a[a]			

[a] n/a = not applicable; there were no successful runs of UV-cured ink on OPP in the performance demonstrations.

Discussion of Cost Analysis Results

Material Costs

Material costs comprised ink and additive costs. Table 5.14 presents these costs. Because no white ink was used on PE/EVA (a white substrate), ink costs for PE/EVA were the lowest.

A significant difference among the three ink systems was the cost of ink. For example, for the performance demonstration runs on LDPE, water-based inks cost an average of $19.19 per 6,000 images, whereas solvent-based inks cost an average of $32.16 (68% more than water-based inks) and UV-cured inks cost an average of $40.82 (113% more than water-based inks). The high price per pound of UV inks contributed to their higher cost, in spite of their lower rate of use per unit of substrate.

Differing ink consumption rates also affected costs. Several factors could have affected consumption rates. Solvent-based ink evaporates more readily, thereby requiring the periodic addition of press-side solvent. (An average of 4.61 pounds ($4.61) of press-side solvent were required per 6,000 images during the performance demonstrations). Solvent-based inks also have a lower solids content; therefore, to deliver an equivalent amount of pigment to the substrate, a greater volume of ink is required. The surface tension of solvent-based inks is lower, and therefore more ink is transferred from the anilox roll given similar anilox roll volumes. Finally, the anilox rolls can dictate the amount of ink consumed; rolls with more volume than necessary may lead to artificially high ink consumption rates.

Table 5.14 Summary of Average Material Costs from the Performance Demonstrations

Substrate	Ink	Average ink costs per 6,000 images	Average ink costs per 6,000 ft^2 of image	Average ink costs % of total	Average additive costs per 6,000 images	Average additive costs per 6,000 ft^2 of image	Average additive costs % of total	Total per 6,000 images	Total per 6,000 ft^2 of image
LDPE	Solvent-based	$40.15	$18.08	88%	$5.61	$2.53	12%	$45.76	$20.61
	Water-based	$23.22	$10.41	96%	$0.86	$0.39	4%	$24.09	$10.80
	UV-cured	$62.79	$28.24	100%	a	a	0%	$62.80	$28.24
PE/EVA	Solvent-based	$29.83	$13.44	89%	$3.78	$1.70	1%	$33.61	$15.14
	Water-based	$12.78	$5.72	98%	$0.23	$0.10	2%	$13.01	$5.82
	UV-cured	$18.85	$8.50	100%	$0.00	$0.00	0%	$18.85	$8.50
OPP	Solvent-based	$26.51	$11.92	84%	$5.11	$2.31	2%	$31.62	$14.23
	Water-based	$21.58	$9.70	97%	$0.58	$0.27	3%	$22.16	$9.97
	UV-cured	There were no successful runs of UV-cured ink on OPP in the performance demonstrations.							

[a]UV ink manufacturers state that extra monomer is typically not added to UV ink; the printer for this demonstration run did add monomer. The cost of this monomer is not known.

Labor Costs

The differences in labor costs among the three ink systems were inversely proportional to press speed (i.e., the higher the press speed, the lower the cost). Table 5.15 presents a summary of average labor costs from the performance demonstrations. Site-specific labor costs and press speeds can be found in Appendix 5-B. Because most of the demonstrations were run between 340 and 450 fpm, the labor costs do not vary much among the demonstration sites. The sites that ran at slower press speeds (Site 3 at 218 fpm and Site 8 at 262 fpm) had higher labor costs for their respective ink-substrate combinations (water-based ink on LDPE and UV-cured on PE/EVA). Conversely, solvent-based ink on OPP had the lowest average labor cost, because Site 10 ran at 600 fpm. These data do not reflect qualitative issues, such as the fact that UV typically requires less press-side adjustment and monitoring. These issues may also affect press availability.

Table 5.15 Summary of Average Labor Costs from the Performance Demonstrations

Substrate	Solvent-based		Water-based		UV-cured	
	per 6,000 images	per 6,000 ft^2 of image	per 6,000 images	per 6,000 ft^2 of image	per 6,000 images	per 6,000 ft^2 of image
LDPE	\$13.88	\$6.25	\$20.77	\$9.35	\$15.89	\$7.15
PE/EVA	\$13.88	\$6.25	\$14.13	\$6.36	\$19.52	\$8.78
OPP	\$11.98	\$5.39	\$13.52	\$6.08	n/a[a]	

[a]n/a = not applicable; there were no successful runs of UV-cured ink on OPP in the performance demonstrations.

Capital Costs

Table 5.16 presents capital costs for each ink system. Capital cost data from the performance demonstrations were not used, due to the variety and ages of the presses. Instead, the capital costs used in this analysis were based on estimates from suppliers and printers, and also based on average press speeds from the performance demonstrations. A sample calculation is provided in Appendix 5-A.

The differences in capital costs were primarily due to the press speeds (i.e., the higher the press speed, the lower the cost). As a result, the solvent-based press was the least expensive (\$29.08 per 6,000 images). The water-based and UV presses were 11% and 33% more expensive, respectively, than the solvent-based press. At the methodology speed, capital costs for a water-based press would be the least expensive. A UV press would be approximately 4% more expensive and a solvent press would be approximately 8% more expensive.

While both new press and retrofit scenarios are presented in this chapter, only the new press scenario was used in the aggregate cost analysis. However, capital costs would be reduced if existing equipment were retrofitted. If a water-based ink press were retrofitted from a solvent-based ink press, instead of purchasing a new press, the total cost for using water-based inks (per 6,000 images or per 6,000 sq. feet of image) could be reduced approximately 12%. If a UV press were retrofitted from a solvent-based or water-based press, the total cost for using UV-cured inks could be reduced approximately 10%.

Table 5.16 Estimated Capital Costs for New Presses

Ink	Cost per 6,000 images	Cost per 6,000 ft^2 of image
Based on Observed Performance Demonstration Press Speeds		
Solvent-based (5 sites)	\$29.08	\$13.10
Water-based (7 sites)	\$32.15	\$14.48
UV-cured (4 sites)	\$38.75	\$17.45
Based on Methodology Press Speed – 500 Feet per Minute		
Solvent-based (5 sites)	\$26.35	\$11.87
Water-based (7 sites)	\$25.33	\$11.41
UV-cured (4 sites)	\$26.35	\$11.87

Energy Costs

Table 5.17 presents energy costs for each ink system. Energy data from the performance demonstrations were not used due to the lack of data. The energy costs used in this analysis were based on estimates from suppliers and printers, as well as average press speeds from the performance demonstrations. A sample calculation is provided in Appendix 5-B, and details about energy consumption are included in Chapter 6, Resource and Energy Conservation. Energy costs were a minor factor in overall costs, averaging 4.7% of the total cost across the eight ink-substrate combinations. Water-based inks were the least expensive; energy costs were 24% and 220% higher for solvent and UV, respectively. At the methodology speed, water-based inks again would have the lowest energy costs. Solvent-based inks would be 52% higher, and UV-cured inks would be 190% higher than water-based inks. Energy costs for UV are particularly high both because the curing lamps require substantial levels of energy, and because all energy is required in the form of electricity. For water- and solvent-based inks, the dryers can be fueled by natural gas, which is considerably less expensive on a per energy unit basis.

Table 5.17 Estimated Energy Costs for Each Ink System

Substrate	Ink	Average electricity costs per 6,000 images	Average electricity costs per 6,000 ft^2 of image	Average electricity costs % of total	Average natural gas costs per 6,000 images	Average natural gas costs per 6,000 ft^2 of image	Average natural gas costs % of total	Total per 6,000 images	Total per 6,000 ft^2 of image
Based on Observed Performance Demonstration Press Speeds									
LDPE	Solvent-based	$0.77	$0.35	55%	$0.64	$0.29	45%	$1.41	$0.64
	Water-based	$0.67	$0.30	47%	$0.74	$0.33	53%	$1.40	$0.63
	UV-cured	$3.09	$1.39	100%	$0.00	$0.00	0%	$3.09	$1.39
PE/EVA	Solvent-based	$0.77	$0.35	55%	$0.64	$0.29	45%	$1.41	$0.64
	Water-based	$0.45	$0.20	47%	$0.50	$0.23	53%	$0.95	$0.43
	UV-cured	$3.80	$1.71	100%	$0.00	$0.00	0%	$3.80	$1.71
OPP	Solvent-based	$0.67	$0.30	55%	$0.55	$0.25	45%	$1.22	$0.55
	Water-based	$0.43	$0.19	47%	$0.48	$0.22	53%	$0.91	$0.41
	UV-cured	There were no successful runs of UV-cured ink on OPP in the performance demonstrations.							
Based on Methodology Press Speed – 500 Feet per Minute									
	Solvent-based	$0.66	$0.30	55%	$0.53	$0.24	45%	$1.19	$0.53
	Water-based	$0.38	$0.17	48%	$0.41	$0.18	52%	$0.78	$0.35
	UV-cured	$2.29	$1.03	100%	$0.00	$0.00	0%	$2.29	$1.03

5.3 DISCUSSION OF ADDITIONAL COSTS

This section discusses major categories of financial costs and benefits that are associated with environmental regulations, pollution prevention opportunities, and environmental practices – items that are often not projected or tracked in conventional accounting measures. It is intended to help the reader focus on additional types of costs that could be useful in an environmental analysis of a flexographic printing operation.

Many environmental costs are obvious, such as purchasing an oxidizer to reduce VOC emissions to levels dictated by air regulations. There are also less obvious costs; for example, an inefficient process that creates waste means that a company is paying for excess raw materials.

Regulatory Costs

As indicated in Chapter 2, several regulations may impact costs for flexographic printers. Compliance may require a capital investment in equipment, such as treatment and control systems, monitoring devices, laboratory facilities, safety equipment, or ongoing monitoring of a system. Regulated wastes may require additional expenditures for on-site storage, hauling, and off-site treatment and disposal. New systems may require additional personnel and may increase energy use. Additional personnel may be needed to run the equipment, analyze wastes, label and handle the wastes, and maintain the paperwork for permitting and reporting. Some of the relevant federal laws and requirements are discussed in Chapter 2.

Also, various state and local regulations may increase flexographic printing costs. For example, printing facilities using water-based inks may be required to install an oxidizer in some states, whereas in other states they may not be required to do so. Also, wastes from water-based inks may or may not be regulated as hazardous material, depending on the formulation.

Non-compliance with environmental regulations may lead to additional costs. Companies that are not in compliance may face the following direct and indirect costs.

- fines levied by regulatory agencies
- legal costs
- property damage and remediation costs
- increased workers' health insurance and compensation
- decreased sales due to negative publicity

Insurance and Storage Requirements

Concrete insurance costs could not be quantified in the performance demonstration runs. However, solvent-based inks, in general, require additional insurance due to their explosive potential and additional storage requirements.

Anecdotally, in a project to reduce ink and cleaning waste for flexographic printers, one facility reported savings in insurance premiums from switching to water-based inks and an aqueous cleaner. The project compared the volume and toxicity of air emissions and liquid wastes produced by the printing processes before and after switching to water-based inks and an aqueous cleaner, and then determined the economics of such processing changes. The facility saved about $500 per year due to lowered insurance premiums based on improved working conditions.[29]

Other Environmental Costs and Benefits

Benefits from sound environmental practices can often impact areas other than production and the environment. Sick days taken by employees may be decreased (and morale improved) by reducing or eliminating hazardous compounds in the workplace. The company's relationships with customers, insurers, investors, and the community can be improved by gaining a reputation as a firm that is dedicated to environmental commitment beyond minimal regulatory compliance.

Many environmental costs and benefits are not solely environmental; utility costs may be categorized as overhead or production costs, and greater profits may result from increased efficiency and improved morale. More efficient use of raw materials will also lead to greater profits. An analysis of the environmental costs may yield a more accurate accounting of a company's expenses and reveal opportunities for cost reduction.

REFERENCES

1. Argent, Dave. Progressive Inks. Written comments to Laura Rubin, Industrial Technology Institute. June 1997.

2. Bateman, Robert. Roplast Industries. Telephone discussion with Laura Rubin, Industrial Technology Institute. May 27, 1997.

3. Daigle, Maurice. Schuster Flexible Packaging. Written comments to Laura Rubin, Industrial Technology Institute. June 1997.

4. Figueria, Lou. FlexPak. Telephone discussion with Laura Rubin, Industrial Technology Institute. May 23, 1997.

5. Neal, Robert. Maine Poly. Telephone discussion with Laura Rubin, Industrial Technology Institute. May 26, 1997.

6. Nigam, Brijesh. Sun Chemical Ink. Written comments to Dennis Chang, Abt Associates, Inc. November 20, 1998.

7. Root, Dave. Georgia Pacific. Telephone discussion with Laura Rubin, Industrial Technology Institute. May 22, 1997.

8. Ross, Alexander. Radtech. Written comments to Karen Doerschug, US EPA. November 12, 1998.

9. Shapiro, Fred. P-F Technical Services, Inc. Written comments to Laura Rubin, Industrial Technology Institute. June 18, 1998.

10. Siciliano, Mike. Bema Film Systems. Written comments to Laura Rubin, Industrial Technology Institute. July 1997.

11. Steckbauer, Steve. Deluxe Packaging. Telephone discussion with Laura Rubin, Industrial Technology Institute. May 26, 1997.

12. Timmerman, Mark. Trinity Packaging. Telephone discussion with Laura Rubin, Industrial Technology Institute. May 20, 1997.

13. Zembrycki, Jerry. Strout Plastics. Written comments to Laura Rubin, Industrial Technology Institute. June 1997.

14. Ellison, Dave. American National Can Company. Written comments to Laura Rubin, Industrial Technology Institute. June 1997.

15. Serafano, John. Western Michigan University. Personal Communication with Laura Rubin, Industrial Technology Institute. March 26, 1997.

16. Rizzo, Tony. Lawson Marden Label. Telephone discussion with Laura Rubin, Industrial Technology Institute. May 22, 1997.

17. Darney, Arsen J., editor. *Manufacturing USA; Industry Analysis, Statistics, and Leading Companies.* 4th Edition, Volume 1. Gale Research, Inc., Detroit; pp.733., 1994.

18. Yeganah, John. Bryce Corporation. Telephone discussion with Laura Rubin, Industrial Technology Institute. May 23, 1997.

19. Jacobs, Eva. *Handbook of U.S. Labor Statistics Employment, Earnings, Prices, Productivity, and other Labor Data: 1996 Edition*., 1996

20. Steemer, Hans. Windmoeller and Hoelscher. Telephone discussion with Laura Rubin, Industrial Technology Institute. May 6, 1997.

21. Heiden, Corey. Kidder Press. Telephone discussion with Trey Kellett, Abt Associates Inc. July 1, 1999.

22. Bemi, Dan and Steve Rach. MEGTEC Systems. Telephone discussion with Trey Kellett, Abt Associates Inc. July 14, 2000.

23. Kottke, Lee. Anguil Environmental Systems, Inc. Telephone discussion with Trey Kellett, Abt Associates Inc. August 2, 2000.

24. Markgraft, Dave. Enercon. Telephone discussion with Laura Rubin, Industrial Technology Institute. February 1998.

25. National Association of Printers and Lithographers. *NAPL Heatset and Non-Heatset Web Press Operations Cost Study; 1989-1990.* Teaneck, NJ, 1990.

26. Bateman, Robert. Roplast Industries. DfE Flexography Project Steering Committee Conference call. March 1999.

27. U.S. Department of Energy. *Electric Power Monthly.* Energy Information Administration, February 2000.

28. U.S. Department of Energy. *Natural Gas Monthly.* Energy Information Administration, February 2000.

29. Miller, Gary, et al. “Ink Cleaner Waste Reduction Evaluation for Flexographic Printers.” EPA/600/R-93/086, 1993.

ADDITIONAL REFERENCES

Tamm, Rex. Daw Ink Company. Written comments to Laura Rubin, Industrial Technology Institute. June 1997.

U.S. Department of Commerce. *1987 Census of Manufacturers.* Bureau of the Census, MC87-1-27B.

Windmoeller and Hoelscher. Personal communication with sales representative of Windmoeller and Hoelscher (401-333-2770). May 1997.